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Higher Off-Axis Electron Cyclotron Current Drive Via 'Top Launch' Approach[1]

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First time in a tokamak, experiments on DIII-D have measured significantly higher off-axis ECCD efficiency using a novel top launch geometry, more than double conventional outside launch, as predicted by quasi-linear Fokker-Planck simulations. The development of efficient off-axis current drive is crucial for economic, steady-state tokamak fusion power plants, and "top-launch" ECCD is predicted to drive strong off-axis currents by injecting EC waves nearly parallel to the vertical resonance plane with a large toroidal steering. Recent DIII-D experiments using a fixed-aiming top-launcher and 2^{nd} harmonic damping have tested three main tenants of top-launch ECCD: a long absorption path, large Doppler shift damping on high energy electrons, and substantially increased ECCD efficiency at mid-radii. The longer interaction zone is confirmed by top-launch measurements of broader power deposition profiles, while shifted O-mode deposition relative to X-mode verifies the predicted longer vertical path for O-mode due to weaker damping. Changing the separation between the ray path and vacuum resonance by scanning magnetic field varies the wave-electron interactions in velocity space, with experiments finding that wave absorption decreases for extreme Doppler shifts where the wave interacts with too few tail electrons. At optimal conditions with strong damping on high v_parallel electrons far from the trapping boundary, the experimental ECCD at rho˜0.5, determined from the change in the magnetic field pitch angles measured by motional Stark effect polarimetry, is greatly enhanced using top-launch compared to the outside launch (60 vs. 25 kA/MW), and is consistent with the predictions from ray tracing code TORAY and quasi-linear Fokker-Planck code CQL3D. Simulations of FNSF, CFETR and DEMO support top-launch ECCD as an improved efficiency off-axis current drive technique for future fusion reactors.

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